application provides a phase separated organic film or structures without liquid crystal droplets.

The present invention provides advantages over the PDLC elements of the prior art. First, the present invention provides cells which have a lower voltage requirement. Second, PDLC cells have a slower switching speed. Third, the present invention allows for the formation of more well-defined geometries in liquid crystal displays. This is particularly true of cells in bulk form.

Claim 25 was also rejected because the wording of this claim was deemed to include a characterization of a method rather than a device. Claim 25 has been amended in light of this rejection. Replacement sheets for pages 16-20 of the application, which includes the claims, are enclosed. Claim 25 now states that the mixture is separable into a microstructure upon simultaneous polymerization and application of polarized light. As claimed, the liquid crystal material is distributed non-randomly relative to the polymer and polarization sensitive material. And the phase separated and photo-aligned polymer is capable of imparting alignment properties to the liquid crystal material. Examples of the non-random nature of the distribution of the liquid crystal are evidenced throughout the specification. By way of example, the liquid crystal material can be purposefully distributed in the form of a layer of liquid crystal material or a layer of liquid crystal microstructures. Claim 25 now distinguishes over reference D1 in that it now claims a non-randomly distributed liquid crystal material with alignment properties." No teaching or suggestion is made in reference D1 regarding PDLCs or other types of liquid crystal cells that provide a non-randomly distributed liquid crystal material as in claim 25. Therefore, claim 25, as amended, is novel and inventive over reference D1.

Furthermore, claim 1 is also novel and inventive over reference D1, because the reference does not teach or suggest a method for fabricating simultaneously a phase separated organic film or structure with alignment as discussed above. Claim 1 has been amended to more particularly emphasize that this method of the present invention includes the forming of a separate and distinct layer of polymer, as opposed to the polymer dispersed liquid crystal droplets disclosed in reference D1. Furthermore, claim 1 has also been amended to emphasize that inducing phase separation and application

of a polarized light, while simultaneous, are distinct steps of this process. It is not necessary for phase separation to be induced by exposure to light, although it may be. Phase separation may also be induced by other mechanisms such as, for example, thermal induction and solvent induction. As mentioned above, the present invention provides advantages not found in the prior PDLC element such as faster switching times, lower voltage requirements and formation of more well-defined geometries. Therefore, we maintain that method claim 1 is also novel over U.S. Patent No. 6,083,575 and family member JP 11153787.

In light of the above discussion, we also maintain that the features of dependent claims 2-6 and 16-18 would not be obvious to the skilled person and therefore request reconsideration of the reasoned statement with regard to these claims.

Claims 11 and 18 have also been amended to more particularly point out features which are not taught or suggested by the prior art. Claims 11 and 18 indicate the formation of microstructures of predetermined geometry which are all adjacent to a substrate. Reference D1, however, discloses liquid crystal droplets (microstructures) which are distributed randomly and continuously, independent of each other (see D1, Column 1, lines 33-36). For claims 11 and 18, the Examiner has not indicated how D1 teaches or suggests a mask positioning step that results in the formulation of the layer of liquid crystals with microstructures adjacent the substrate. Therefore, claims 11 and 18 are novel and inventive over D1.

With regard to Section VII, please find enclosed replacement pages 3 and 3A which include a description of the relevant background art disclosed in reference D1.

The Examiner stated in Section VIII that the feature of "applying polarized light and inducing simultaneously phase separation of said mixture and alignment of the phase separated liquid crystal" is considered essential to the definition of the invention. In response, we call attention to page 5, lines 22-32 of the present application, which indicates that the mixture may be treated by a process from the group consisting of at least visible light polarization, ultraviolet light polarization, thermal induction, chemical

induction and solvent induction. Therefore, the above-described "applying" step should not be deemed essential to the definition of the invention when it is readily apparent that other combinations of processes can achieve the same result. Reconsideration of this observation is requested.

We also note the Examiner's suggestion for overcoming an objection regarding claim 19 and dependent claims 20-23 regarding an alleged lack of conciseness. The Examiner suggested the filing of an amended set of claims defining the relevant subject matter in terms of a single independent claim in each category. It was further suggested that such an amendment would place the claims in conformity with the requirements of Rule 6.4 PCT. However, because such claim structure is permitted in some designated states, such as the U.S., we request that consideration of this rejection be deferred until the National/Regional Phase.

The Examiner further stated that the subject matter of the dependent claims 7-13 and 26-29 was not clear. The Examiner alleged that these claims related to the manufacture of a separate alignment layer to provide alignment to the liquid crystal layer deposited in contact with the alignment layer. The Examiner stated that such an embodiment contradicted the description as stated on page 3, lines 27-30. These dependent claims, however, are directed toward the "multi-step method" as described in the specification on page 11, line 17 through page 15, line 2. While some of the claims in the present application may be applicable to either the "single step" or "multi-step" methods, claims 7-13 and 26-29 are specifically directed toward the multi-step methods as described in the above-referenced section of the application. The formation of additional alignment layers as in these claims allows the production and use of additional types of liquid crystal cells. These include cells having microstructures adjacent to a substrate as described above. Additional types of cells allowed by this aspect of the present invention include those utilizing twisted nematic liquid crystal material for creation of twisted nematic cells.

Finally, the Examiner found the dependency of claim 24 to be unclear. Claim 24 now depends from claim 19 and specifies that the step of permitting phase separation separates the prepolymer and polarization sensitive agent from the liquid crystal.

If the Examiner should have any questions or wish to discuss any aspect of this Response to the PCT Written Opinion, the undersigned would welcome a telephone call from the Examiner.

Respectfully submitted,

Dated: 25 October 2001

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alignment is lost upon exposure to normally occurring un-polarized UV light. Moreover, the chemical composition of the materials is lost over time. Consequently, the alignment layer thus produced does not provide a fixed, stable orientation of liquid crystal material.

Yet another method for forming an alignment layer on a substrate is deposition by evaporation of inorganic materials onto the surface of the substrate at various incidence angles. This forms an alignment layer which physically orients the director of the liquid crystal. Inorganic materials which have been used include silicon oxides and magnesium oxides. This deposition method has proven to be cumbersome and difficult to use in a manufacturing process.

Another process for forming alignment layers, developed by Kent State University, is the *in-situ* UV exposure method. This method is disclosed in U.S. Patent No. 5,936,691, and is incorporated herein by reference. The *in-situ* method is similar to the conventional process of exposing PI film to polarized UV light. The *in-situ* method, however, exposes the polyimide film (PI) to UV radiation while the film is being soft- and hard-baked. The resulting alignment layers have higher anchoring energies and are thermally more stable compared to the conventional UV exposure technique. For example, cells prepared with the conventional method lose alignment when maintained at 100 °C for 12 hours, while cells prepared by the *in-situ* method, show no sign of deterioration at 300 °C for 12 hours. The *in-situ* method of forming an alignment layer avoids many of the drawbacks of other methods known in the art, while requiring fewer and simpler processing steps.

Although the *in-situ* method has been shown to be effective, it still requires that the alignment film must still be properly disposed and processed. Moreover, for all the alignment methods discussed above, the alignment layer may be damaged if care is not taken in transferring the substrate between the manufacturing stations. It is also theorized that currently known alignment layers only directly affect the liquid crystal material adjacent thereto.

It has also been disclosed in U.S. Pat. No 6,083,575 that a polymer dispersion type liquid crystal (PDLC) element may be manufactured by applying laser interference light to a polymerizable composition containing a polymerizable compound having a photo-dimerizable structure and low molecular weight liquid crystals. The laser interference light causes polymer phase separation. Polarized light is then applied to orient the low molecular liquid crystal. As stated in that patent, a polymer dispersion type liquid crystal is a display

element in which liquid crystals are dispersed in the interstices of polymers of a three dimensional structure. However, while U.S. Pat. No. 6,083,575 teaches the use of a photo-sensitive polymer, the teachings of this patent are limited to polymer dispersion type liquid crystal cells. Various limitations are inherent in PDLC cells however, compared to cells using phase separated composite organic films for example. PDLC cells have higher voltage requirements, slower switching speeds and very low multiplexability. Phase separated composite organic films also allow for the formation and use of more-well defined geometries in liquid crystal displays, especially in bulk form. No teaching or suggestion is made regarding the construction of a liquid crystal element of a type other than a polymer dispersion type liquid crystal, such as a phase-separated composite organic film as present in the present application or the use of photo-sensitive polymers to create an alignment film.

In light of the foregoing, it is evident that there is a need in the art for a light modulating device comprising a phase separated composite organic film, and a method for manufacturing such a film, that is homogeneously aligned during formation, thus obviating the need for the preparation and processing of a separate and distinct alignment layer.

What is claimed is:

1. A method for fabricating simultaneously a phase separated organic film with alignment, comprising:

preparing a mixture of liquid crystal, prepolymer and a polarization-sensitive material;

disposing said mixture on a substrate;

applying a polarized light from a light source, and

inducing phase separation of said mixture simultaneously during said applying step, thereby forming a separate layer of homogeneously aligned liquid crystal material adjacent a separate and distinct layer of polymer and said polarization-sensitive material on said substrate, wherein alignment of the phase separated liquid crystal layer is induced by the alignment of the polymer and polarization-sensitive material layer.

2. The method according to claim 1, further comprising:

disposing a second substrate over said layers.

3. The method according to claim 1, wherein said applying step causes at least a major portion of said polarization-sensitive material to mix with said prepolymer, said polarization-sensitive material imparting alignment properties to said liquid crystal material.

4. The method according to claim 1, further comprising:

interposing a polarizer between said light source and said substrate to impart a desired orientational alignment to said liquid crystal material.

5. The method according to claim 4, further comprising:

positioning an ultraviolet light source near said substrate opposite the side with said disposed mixture.

6. The method according to claim 4, further comprising:

positioning a visible light source near said substrate opposite the side with said disposed mixture.

7. The method according to claim 2, further comprising:

preparing an initial mixture of an initial prepolymer and an initial polarization-sensitive material; and

coating said initial mixture on said second substrate prior to said mixture disposing step.

8. The method according to claim 7, wherein said initial polarization-sensitive material is sensitive to a different wavelength of light than said polarization-sensitive material.

9. The method according to claim 8, further comprising:

applying an initial polarized light to said initial mixture prior to said mixture disposing step to impart an alignment orientation thereto.

10. The method according to claim 8, further comprising:

applying an initial polarized light to said initial mixture after said mixture disposing step to impart an alignment orientation thereto.

11. The method according to claim 10, further comprising:

positioning a mask and a polarizer between said light source and said substrate prior to said applying step so as to form said layer of liquid crystal with microstructures, wherein all of said microstructures are adjacent to said second substrate.

12. The method according to claim 11, further comprising:

positioning another mask between said light source and said substrate after said initial applying step.

13. The method according to claim 7, wherein said initial polarization-sensitive material and said polarization material are activated by either ultraviolet or visible light.

14. The method according to claim 1, wherein said prepolymer is a thermally activated prepolymer, and wherein said step of inducing phase separation includes thermally activating said mixture to induce phase separation.

15. The method according to claim 14, wherein said polarized light is either visible or ultraviolet.

16 The method according to claim 7, further comprising:

preparing said initial mixture with epoxy and resin; and

permitting phase separation of said initial mixture to induce phase separation of said initial mixture and impart an alignment orientation to said liquid crystal.

17. The method according to claim 16, wherein said polarized light is either visible or ultraviolet.

18. The method according to claim 2, further comprising:

positioning a mask and a polarizer between said light source and said substrate prior to said applying step so as to form said layer of liquid crystal with microstructures, wherein all of said microstructures are adjacent to said second substrate.

19. A method for fabricating a liquid crystal device with alignment properties comprising:

providing a substrate;

providing a first mixture comprising at least a first polarization-sensitive agent, and a prepolymer;

providing a second mixture comprising at least a second polarization-sensitive agent and a prepolymer;

mixing into either said first or second mixture a liquid crystal;

disposing said first mixture on to said substrate;

disposing said second mixture over said first mixture;

initiating a first phase separation process to said first mixture from the group consisting of at least visible light polarization, ultraviolet light polarization, thermal induction, chemical induction, and solvent induction,

initiating a second phase separation process to said second mixture from the group consisting of at least visible light polarization, ultraviolet light polarization, thermal induction, chemical induction, and solvent induction; and

said processes imparting orientational alignments to said liquid crystal.

20. The method according to claim 19, wherein one of said initiating steps includes at least simultaneous application of one of said polarization processes and one of said induction processes so as to phase separate said liquid crystal from said prepolymer.

21. The method according to claim 19, further comprising:

securing a second substrate to said first substrate with said first and second mixtures therebetween.

22. The method according to claim 19, wherein said polarization processes comprise:

positioning a light source near said substrate, and

positioning a polarizer between said substrate and said light source.

23. The method according to claim 19, further comprising:

re-positioning said polarizer after said first initiating step, wherein said polarization-sensitive agents impart different orientational alignments at their respective interfaces with said liquid crystal

24. The method according to claim 19, wherein said first or second phase separation process separates said prepolymer and said polarization-sensitive agent from said liquid crystal.

25. A cell having alignment properties, comprising:

at least one substrate; and

a mixture disposed on said substrate, said mixture comprising at least a liquid crystal material, a prepolymer material and a polarization-sensitive material, wherein said mixture is capable of separation into a microstructure of liquid crystal material adjacent polymer and polarization-sensitive material upon polymerization of the prepolymer and simultaneous exposure to polarized light, wherein said liquid crystal

material is distributed non-randomly relative to said polymer and polarization sensitive material, and wherein said polymer and polarization-sensitive material layer is capable of imparting alignment properties to said liquid crystal material.

26. The cell according to claim 25, further comprising.

a second mixture disposed on said substrate prior to said first mixture, said second mixture comprising at least a second polarization-sensitive material and

wherein application of polarized light causes photo-alignment of said second mixture that imparts alignment properties to said liquid crystal material.

27. The cell according to claim 26, wherein distinct and separate interfaces are formed between said liquid crystal material and said microstructure of polymer and said polarization-sensitive material, and between said liquid crystal material and said second polarization-sensitive material.

28. The cell according to claim 27, wherein said interfaces align said liquid crystal material in different orientations.

29. The cell according to claim 28, wherein said liquid crystal material is formed into microstructures.

alignment is lost upon exposure to normally occurring un-polarized UV light. Moreover, the chemical composition of the materials is lost over time. Consequently, the alignment layer thus produced does not provide a fixed, stable orientation of liquid crystal material.

Yet another method for forming an alignment layer on a substrate is deposition by evaporation of inorganic materials onto the surface of the substrate at various incidence angles. This forms an alignment layer which physically orients the director of the liquid crystal. Inorganic materials which have been used include silicon oxides and magnesium oxides. This deposition method has proven to be cumbersome and difficult to use in a manufacturing process.

Another process for forming alignment layers, developed by Kent State University, is the *in-situ* UV exposure method. This method is disclosed in U.S. Patent No. 5,936,691, and is incorporated herein by reference. The *in-situ* method is similar to the conventional process of exposing PI film to polarized UV light. The *in-situ* method, however, exposes the polyimide film (PI) to UV radiation while the film is being soft- and hard-baked. The resulting alignment layers have higher anchoring energies and are thermally more stable compared to the conventional UV exposure technique. For example, cells prepared with the conventional method lose alignment when maintained at 100 °C for 12 hours, while cells prepared by the *in-situ* method, show no sign of deterioration at 300 °C for 12 hours. The *in-situ* method of forming an alignment layer avoids many of the drawbacks of other methods known in the art, while requiring fewer and simpler processing steps.

Although the *in-situ* method has been shown to be effective, it still requires that the alignment film must still be properly disposed and processed. Moreover, for all the alignment methods discussed above, the alignment layer may be damaged if care is not taken in transferring the substrate between the manufacturing stations. It is also theorized that currently known alignment layers only directly affect the liquid crystal material adjacent thereto.

In light of the foregoing, it is evident that there is a need in the art for a light modulating device comprising a phase separated composite organic film, and a method for manufacturing such a film, that is homogeneously aligned during formation, thus obviating the need for the preparation and processing of a separate and distinct alignment layer.

What is claimed is:

1. A method for fabricating simultaneously a phase separated organic film with alignment, comprising:

preparing a mixture of liquid crystal, prepolymer and a polarization-sensitive material;

disposing said mixture on a substrate; and

applying a polarized light from a light source and inducing simultaneous phase separation of said mixture and alignment of the phase separated liquid crystal so as to form a layer of homogeneously aligned liquid crystal material adjacent a layer of polymer and said polarization-sensitive material on said substrate.

2. The method according to claim 1, further comprising:

disposing a second substrate over said layers.

3. The method according to claim 1, wherein said applying step causes at least a major portion of said polarization-sensitive material to mix with said prepolymer, said polarization-sensitive material imparting alignment properties to said liquid crystal material.

4. The method according to claim 1, further comprising:

interposing a polarizer between said light source and said substrate to impart a desired orientational alignment to said liquid crystal material.

5. The method according to claim 4, further comprising:

positioning an ultraviolet light source near said substrate opposite the side with said disposed mixture.

6. The method according to claim 4, further comprising:

positioning a visible light source near said substrate opposite the side with said disposed mixture.

7. The method according to claim 1, further comprising:

preparing an initial mixture of an initial prepolymer and an initial polarization-sensitive material; and

coating said initial mixture on said substrate prior to said disposing step.

8. The method according to claim 7, wherein said initial polarization-sensitive material is sensitive to a different wavelength of light than said polarization-sensitive material.

9. The method according to claim 8, further comprising:

applying an initial polarized light to said initial mixture prior to said disposing step to impart an alignment orientation thereto.

10. The method according to claim 8, further comprising:

applying an initial polarized light to said initial mixture after said disposing step to impart an alignment orientation thereto.

11. The method according to claim 10, further comprising:

positioning a mask and a polarizer between said light source and said substrate prior to said applying step so as to form said layer of liquid crystal with microstructures.

12. The method according to claim 11, further comprising:

positioning another mask between said light source and said substrate after said initial applying step.

13. The method according to claim 7, wherein said initial polarization-sensitive material and said polarization material are activated by either ultraviolet or visible light.

14. The method according to claim 1, further comprising:

preparing said mixture with at least a thermally activated prepolymer; and

thermally activating said mixture to induce phase separation and impart an alignment orientation to said liquid crystal.

15. The method according to claim 14, wherein said polarized light is either visible or ultraviolet.

16. The method according to claim 1, further comprising:

preparing said mixture with epoxy and resin; and

permitting phase separation of said mixture to induce phase separation of said mixture and impart an alignment orientation to said liquid crystal.

17. The method according to claim 16, wherein said polarized light is either visible or ultraviolet.

18. The method according to claim 1, further comprising:

positioning a mask and a polarizer between said light source and said substrate prior to said applying step so as to form said layer of liquid crystal with microstructures.

19. A method for fabricating a liquid crystal device with alignment properties comprising:

providing a substrate;

providing a first mixture comprising at least a first polarization-sensitive agent, and a prepolymer;

providing a second mixture comprising at least a second polarization-sensitive agent and a prepolymer;

mixing into either said first or second mixture a liquid crystal;

disposing said first mixture on to said substrate;

disposing said second mixture over said first mixture;

initiating a process to said first mixture from the group consisting of at least visible light polarization, ultraviolet light polarization, thermal induction, chemical induction, and solvent induction;

initiating a process to said second mixture from the group consisting of at least visible light polarization, ultraviolet light polarization, thermal induction, chemical induction, and solvent induction; and

said processes imparting orientational alignments to said liquid crystal.

20. The method according to claim 19, wherein one of said initiating steps includes at least simultaneous application of one of said polarization processes and one of said induction processes so as to phase separate said liquid crystal from said prepolymer.

21. The method according to claim 19, further comprising:

securing a second substrate to said first substrate with said first and second mixtures therebetween.

22. The method according to claim 19, wherein said polarization processes comprise:

positioning a light source near said substrate; and

positioning a polarizer between said substrate and said light source.

23. The method according to claim 19, further comprising:

re-positioning said polarizer after said first initiating step, wherein said polarization-sensitive agents impart different orientational alignments at their respective interfaces with said liquid crystal.

24. The method according to claim 17, wherein said induction process phase separates said prepolymer and said polarization-sensitive agent from said liquid crystal.

25. A cell having alignment properties, comprising:

at least one substrate; and

a mixture disposed on said substrate, said mixture comprising at least a liquid crystal material, a prepolymer material and a polarization-sensitive material, wherein simultaneous polymerization and application of polarized light causes phase separation and photo-alignment of said mixture, thus forming a microstructure of polymer that imparts alignment properties to said liquid crystal material.

26. The cell according to claim 25, further comprising:

a second mixture disposed on said substrate prior to said first mixture, said second mixture comprising at least a second polarization-sensitive material and

wherein application of polarized light causes photo-alignment of said second mixture that imparts alignment properties to said liquid crystal material.

27. The cell according to claim 26, wherein distinct and separate interfaces are formed between said liquid crystal material and said microstructure of polymer and said polarization-sensitive material, and between said liquid crystal material and said second polarization-sensitive material.

28. The cell according to claim 27, wherein said interfaces align said liquid crystal material in different orientations.

29. The cell according to claim 28, wherein said liquid crystal material is formed into microstructures.

ABSTRACT OF THE DISCLOSURE

A method for simultaneously fabricating a phase separated organic film and microstructures with liquid crystal having desired alignment is disclosed. The method includes the step of preparing a mixture of liquid crystal material, prepolymer, and polarization-sensitive material. The mixture is disposed on a substrate and a combination of UV or visible light or heat treatment is applied while simultaneously inducing phase separation so as to form a layer or microstructure of appropriately aligned liquid crystal material adjacent the substrate.